Current Status of $K^+ \to \pi^0 \mu^+ \nu_\mu \gamma$ study

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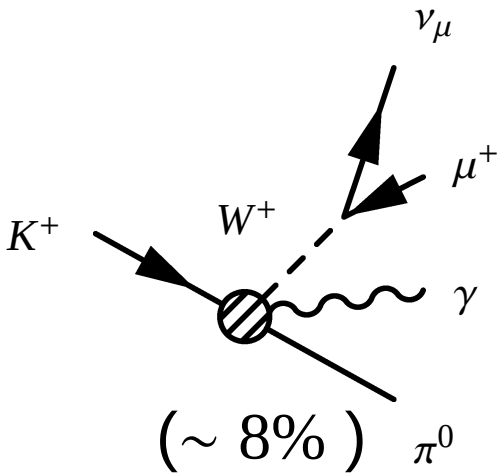
Physics Motivations

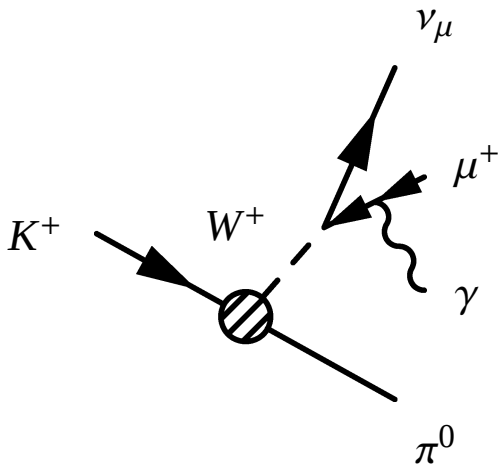
Chiral Perturbation Theory

QCD effective theory in low energy region

quark field → pseudoscalar meson field

(using Only Chiral Symmetry)



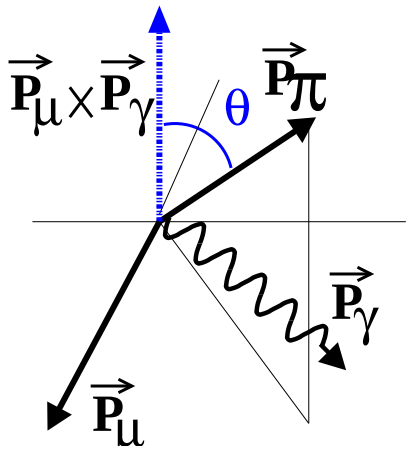


Structure Dependent Internal Bremsstrahlung

Branching ratio is predicted as $\sim 2.0 \times 10^{-5}$
$(E_\gamma > 30MeV, \theta_{\mu\gamma} > 20^\circ)$

T-violation

$\vec{P_\pi} \cdot (\vec{P_\mu} \times \vec{P_\gamma})$



$N_+ \equiv$ Number of $\theta < \pi/2$

$N_- \equiv$ Number of $\theta > \pi/2$

$$A_\xi = \frac{N_+ - N_-}{N_+ + N_-}$$

(π up-down asymmetry against the "$\mu - \gamma$ plane")

within SM, this $A_\xi = 1.14 \times 10^{-4}$ due to final state interaction.
probe to the physics beyond SM(hep-ph/0305067)

Experimental Status

Previous exp.@Argonne National Laboratory (PR D8 1307(1973))

No events were observed. :

$$BR < 6.1 \times 10^{-5} (CL = 90\%)$$

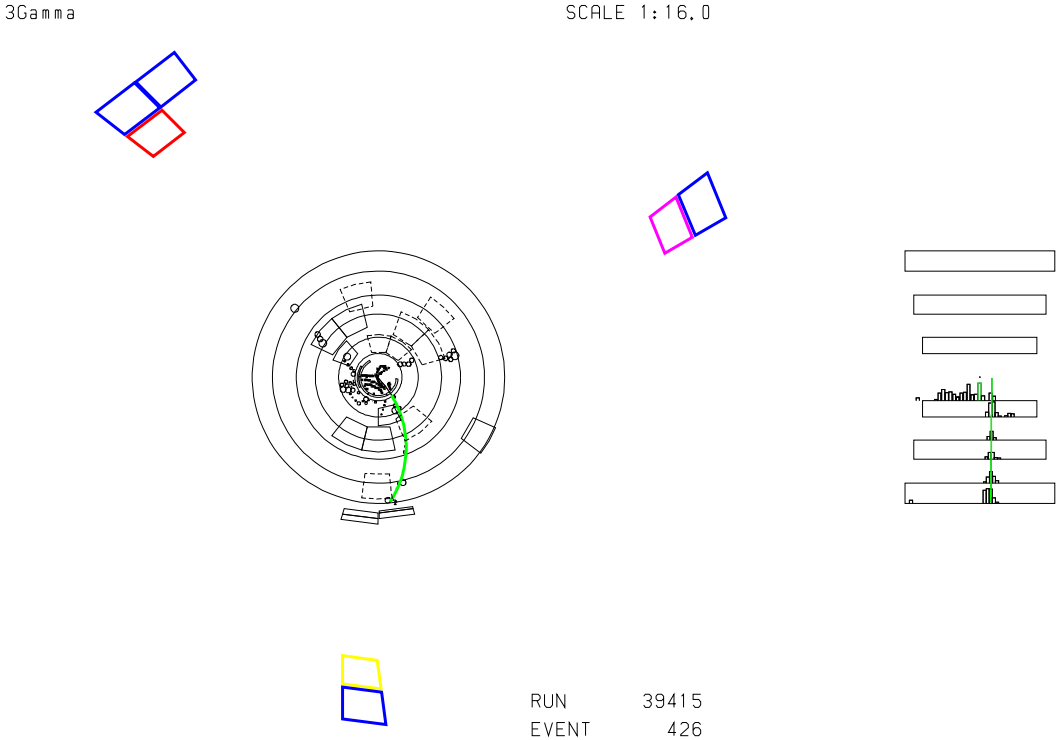
No observation yet!

Other $K_{l3\gamma}$ decays are already measured...

- ★ $K^{+}_{e3\gamma}$ ... $(2.62 \pm 0.20) \times 10^{-4}$
- ★ $K^{0}_{e3\gamma}$ ... $(3.62^{+0.26}_{-0.21}) \times 10^{-3}$
- ★ $K^{0}_{\mu 3\gamma}$ ... $(5.7^{+0.6}_{-0.7}) \times 10^{-4}$

Structure Dependent Term: NOT MEASURED!

Event Display

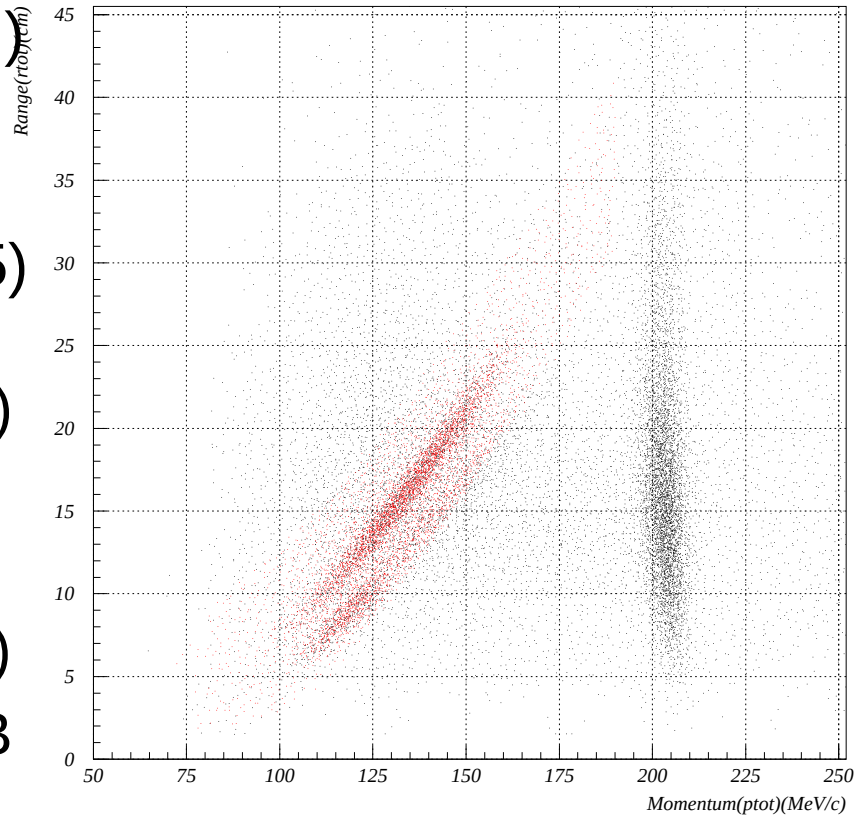


- ★ 3γ clusters in Barrel Veto
- ★ Right Stopping Counter
- ★ No Extra Activity

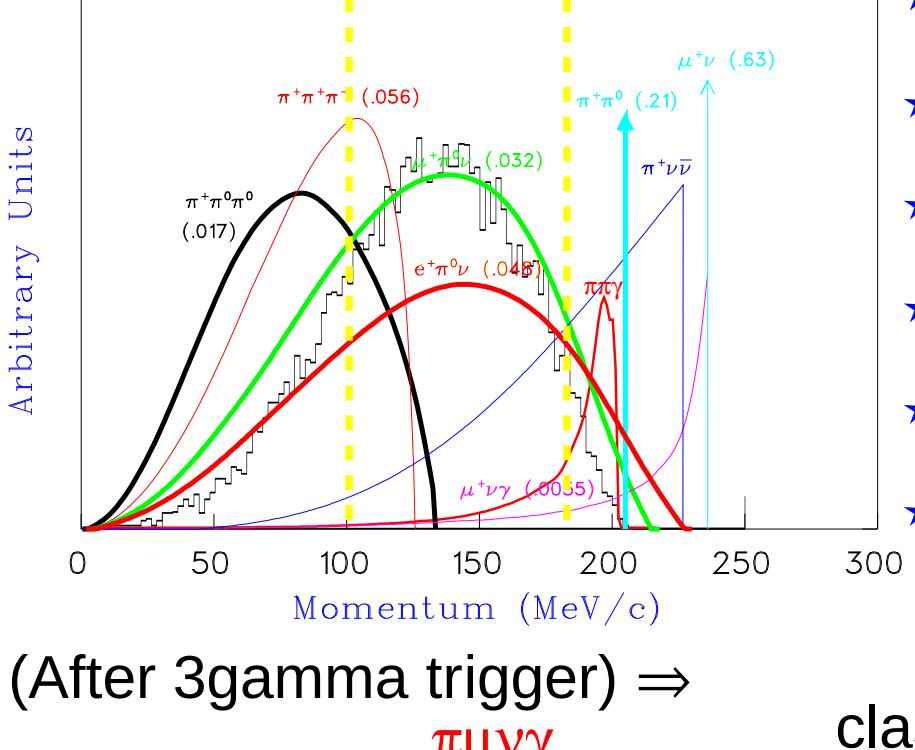
G3PASS1/G3PASS2

- ★ PASS1 (common to $K_{\mu 3\gamma}/K_{\pi 2\gamma}$ ana.)
  - Data Set: DLT * 35
  - Number of KB_LIVE: 1.86×10^{12}
    (1.4 times larger than that of '95)
  - Data Reduction:
    1TB $\rightarrow$ 346GB(33.8%)(DLT*13)

- ★ PASS2 (for $K_{\mu 3\gamma}$)
  (not so tight for Background study)
  - Data Reduction: 346GB $\rightarrow$ 60GB



Backgrounds Sources



- ★ $\pi^0\mu^+\nu_\mu$ +accidental/splitted γ
- ★ $\pi^0 e^+\nu_e$ +accidental/splitted γ
- ★ $\pi^+\pi^0\pi^0$ +missing/overlapping γ
- ★ $\pi^+\pi^0\gamma$
- ★ $\pi^+\pi^0$ +accidental/splitted γ
- ★ $\pi^0\pi^0\mu^+\nu_\mu$ negligible??

(After 3gamma trigger) ⇒

or

classfication by # of γs

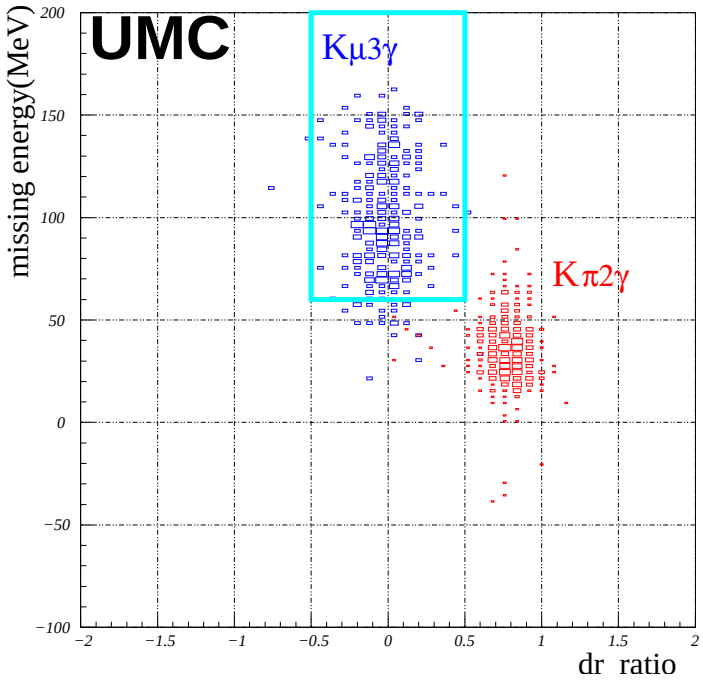
- ★ 4γ + 1γ is missed
  and/or charged track miss-ID
- ★ 3γ + charged track miss-ID
- ★ 2γ + fake γ
  and/or charged track miss-ID

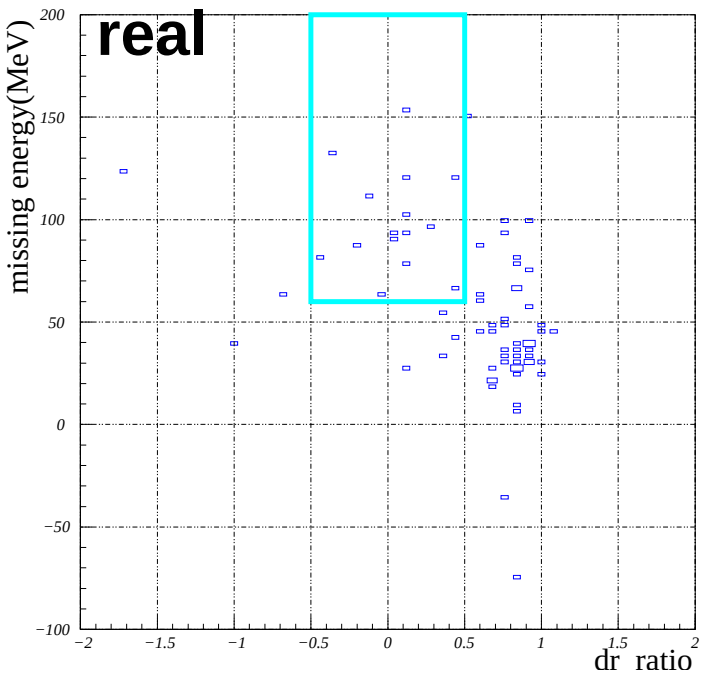
what was problem

- ★ background estimation was still imperfect.
  - $K\pi 2\gamma$ background no concrete estimation.

$K_{\pi 2\gamma}$ background estimation

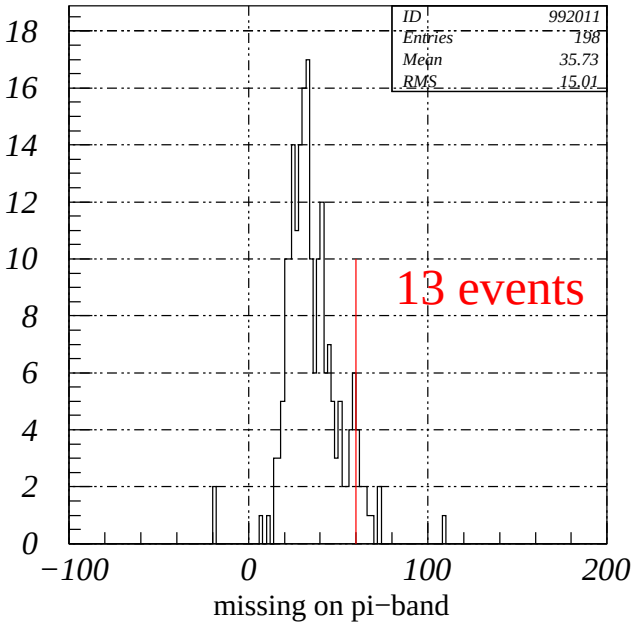
pure UMC-based estimation(using *corrected* F_s): <0.194(90%CL)



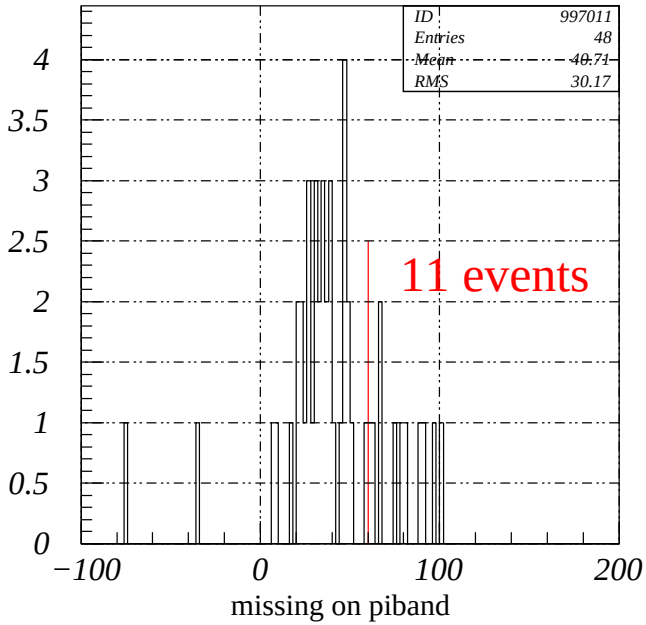


missing energy tail of $K_{\pi 2\gamma}$ peak

UMC data

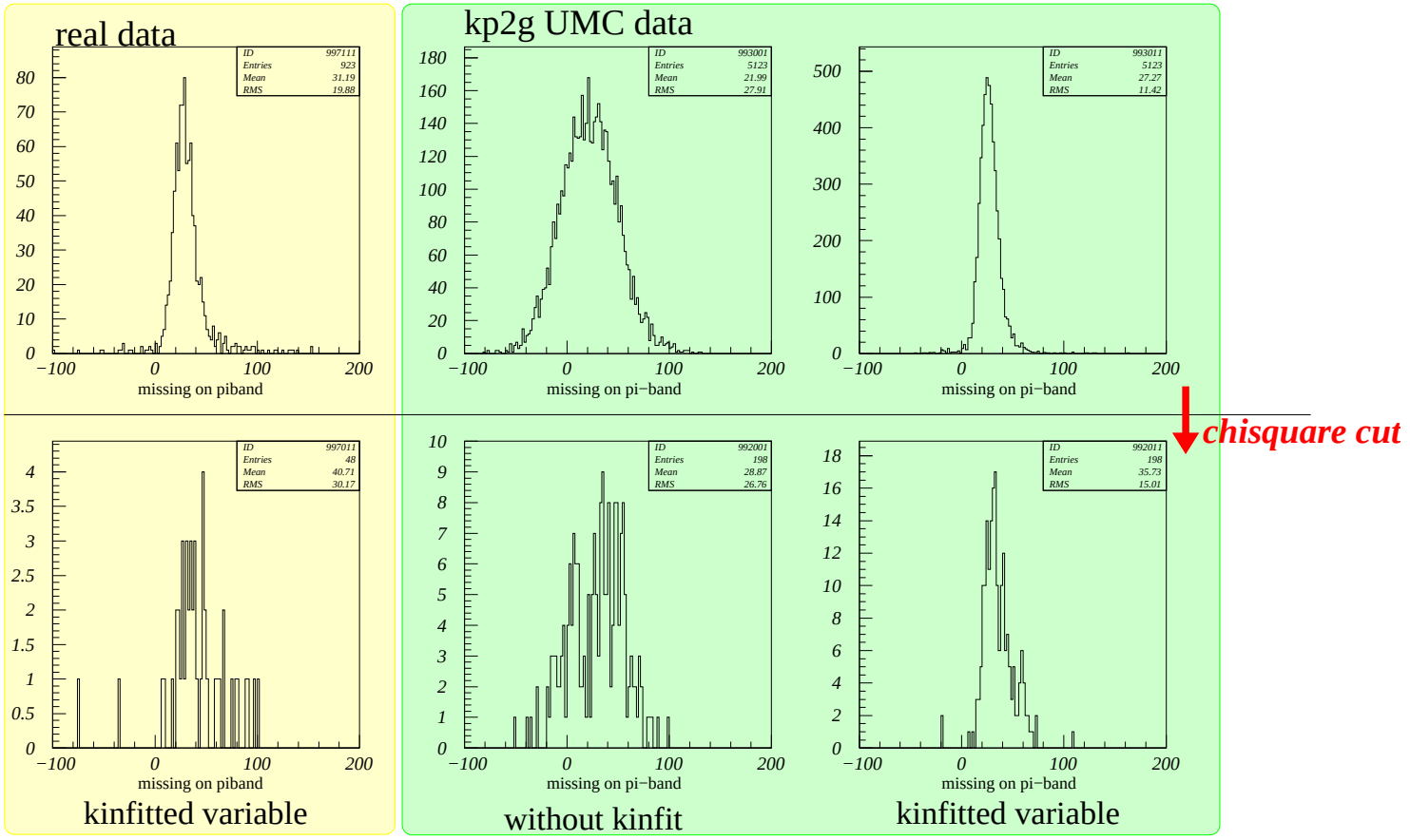


real data



UMC doesn’t reprouduce missing energy distribution of real data.

kinfit tuning problems



Inconsistency might comes from different kinfit tunings between UMC and real data.

biased sample for $K_{\pi 2\gamma}$

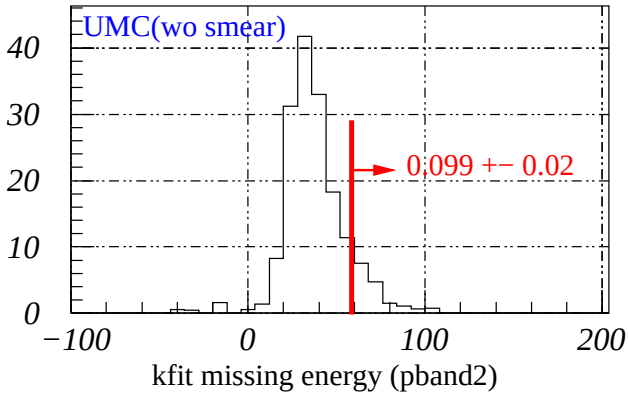
G3PASS2 muon band cut is tight for $K_{\pi 2\gamma}$ G3PASS2/wo tight muon band was produced for this study.

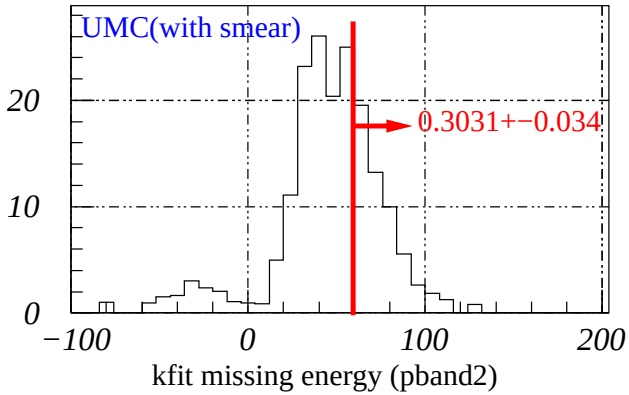
Kinfit tuning

smearing UMC data in order to use same kinematic fitting parameters.
smeared variable set is same to TN370('95 $K_{\pi 2\gamma}$)

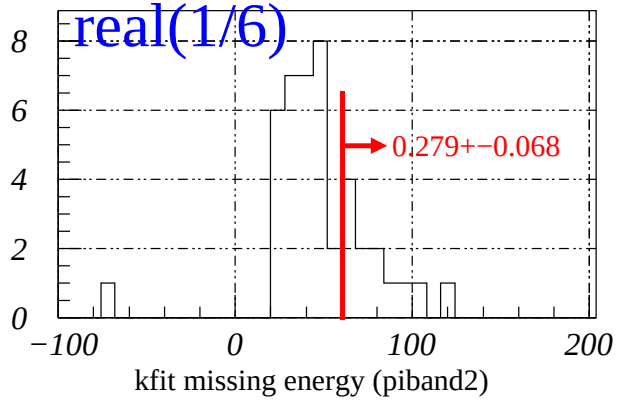
$etot = etot + 2.73 * \sigma$
$ptot = ptot + 2.45 * \sigma$
$E_\gamma = E_\gamma + 0.692\ \sqrt{E_\gamma}\sigma$
BV z offset $\Leftarrow$ no smearing

Kinfit tuning result





real(1/6)



Kp3 acceptance in this region(pion band) is enhanced.

new problem

absolute value of expected events in/out of signal BOX is not consistent with UMC expectation.

- ★ $K_{\mu 3\gamma}$ acceptance $\leftarrow$ due to EGCUT

details will be studied.

Dicay-in-flight enhanced $K_{\pi 2\gamma}$ *UMC*

Decay-in-flight enhanced:
event generation is discarded if π^+ stops due to energy loss.
This will help when missing energy tail is well understood.

Background summary

From 1/3 sample study

sources	#events
$K_{\pi 3}$	0.614+ <1.84
$K_{\pi 2\gamma}$	<0.194?
$K_{\mu 3} + Acc$	0.803
$K_{\mu 3}$+ splitted γ	negligible
$K_{e3}/K_{e3\gamma}$	0.505
All Backgrounds	1.92 +<2.03

$K_{\pi 2\gamma}$ study is still imperfect.

Analysis schedule

Problems

- ⋆ $K_{\pi 2\gamma}$ background estimation is still imperfect
- ⋆ kinfit tuning consistency(or do away with kinematic fitting)

Full(or 2/3) sample study

- ⋆ background estimation consistency check
- ⋆ Physics result

Summary

- ★ checked that smearing is important. But It needs more study.

TODO

- ★ $K_{\pi 2\gamma}$ background study.
- ★ Positve Evidence of signal good final plot(s)
- ★ Physics Results